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J. L. Nelssen
University of Nebraska-Lincoln

A. J. Lewis
University of Nebraska-Lincoln, alewis2@unl.edu

E. R. Peo
University of Nebraska-Lincoln

J. D. Crenshaw
University of Nebraska-Lincoln

EFFECT OF DIETARY ENERGY INTAKE DURING LACTATION ON PERFORMANCE OF PRIMIPAROUS SOWS AND THEIR LITTERS[1,2]

J. L. Nelssen[3], A. J. Lewis[4], E. R. Peo, Jr. and J. D. Crenshaw

University of Nebraska[5],
Lincoln 68583-0908

ABSTRACT

A total of 146 primiparous sows was used in four replications of an experiment to investigate the effect of energy intake during a 28-d lactation on sow and litter performance. Dietary treatments consisted of three energy intakes; 10, 12 or 14 Mcal of metabolizable energy (ME)•sow^{-1}•d^{-1}. All sows were fed equal amounts of crude protein, vitamins and minerals daily, which met or exceeded standard recommendations. The experiment was initiated at parturition. Sow weight and backfat loss during lactation decreased linearly (P<.001) as energy intake increased. There were no differences in litter size at either 14 d of lactation or weaning. Pig weights on d 14 increased linearly (P<.05) and litter weights tended to increase linearly (P=.13) as energy intake increased. At weaning, pig weights and litter weights increased (P<.05) as sow energy intake increased. There were no significant differences in the percentages of sows in estrus by 7, 14, 21 and 70 d postweaning, but sows fed 10 Mcal ME/d had a slightly longer interval from weaning to first estrus than sows fed higher energy intakes. Serum urea concentrations of sows were inversely related to energy intake during lactation. Serum creatinine concentrations were not affected by energy intake. An intake of 10 Mcal ME/d by primiparous sows during a 28-d lactation resulted in reduced sow and litter performance; there was little difference between sows fed 12 and 14 Mcal ME/d.

(Key Words: Sows, Lactation, Energy Intake, Performance, Estrus.)

Introduction

An important component of the overall reproductive efficiency of sows is the length of the interval from weaning to first estrus. A short interval is necessary to maximize the number of pigs marketed per sow per year. Unfortunately, primiparous sows often have relatively long intervals (Fahmy et al., 1979; Love, 1979; Szarek et al., 1981). Various factors have been shown to affect the interval from weaning to estrus in sows. These factors include litter size (Stevenson and Britt, 1981), litter-suckling pattern (Britt and Levis, 1982) and energy intake during lactation (Reese et al., 1982a; Cox et al., 1983).

The National Research Council (NRC, 1979) recommended a minimum metabolizable energy (ME) intake of 12.8 Mcal/d for both primiparous and multiparous sows during lactation. There has, however, been little research to establish the energy requirement of primiparous sows for optimum reproductive performance. Reese et al. (1982a) found that the percentage of primiparous sows that exhibited estrus within 7 d after weaning was >90% when sows were fed ⩾12 Mcal ME/d, but was ⩽65% when they were fed 8 Mcal ME/d. Cox et al. (1983) reported that lactating primiparous sows consumed an estimated 8.9 Mcal ME/d of a control diet and 9.6 Mcal ME/d of a diet with 10% added fat. The percentage of these sows in estrus by 10 d postweaning varied from 34 to >80%, depending on energy intake and season of the year (lower in summer than in winter).

The objectives of the experiment reported herein were to determine the energy intake required for primiparous sows to: (1) produce satisfactory sow and litter performance during

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[3] Present address: Dept. of Anim. Sci. and Industry, Kansas State Univ., Manhattan 66506.

[4] To whom reprint requests should be addressed.

[5] Dept. of Anim. Sci.

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lactation and (2) prevent a delay in return to estrus postweaning.

Experimental Procedure

One hundred forty-six primiparous sows (Landrace × Large White × Duroc × Hampshire) were fed 1.8 $kg \cdot sow^{-1} \cdot d^{-1}$ of a 14% crude protein gestation diet (table 1) until d 108 of gestation. On d 108, the sows were moved into farrowing crates and were fed 2.27 kg/d of the diet designated as 10 Mcal ME/d in table 1 until parturition. The sows farrowed in January, June, September and November 1982 (replications 1 through 4, respectively). At parturition, groups of three sows were randomly assigned to diets that provided energy intakes of 10, 12 or 14 Mcal $ME \cdot sow^{-1} \cdot d^{-1}$ (table 1). The sows were fed the experimental diets during a 28-d lactation period. One-half of the daily feed allowance was given during the morning and one-half in the afternoon. Each of the three diets was formulated to provide 22% of the energy intake from tallow. All sows received the same daily allowances of protein, vitamins and minerals, which met or exceeded the recommendations of the NRC (1979).

On d 110 of gestation and d 14 and 28 of lactation, sow backfat thickness was measured ultrasonically. On the same days, a sample of blood was collected from the brachial region in an evacuated glass tube. Sows were bled 3.5 h after the morning feeding. Blood samples were placed in an ice bath after collection and were stored at 4 C until centrifugation (1,400 × g for 20 min, at 2 C) to separate serum. Serum samples were stored at −20 C until analyzed for urea and creatinine. Serum urea and creatinine concentrations were determined by the automated procedures described by Marsh et al. (1965) and Frankel et al. (1970), respectively.

Sows and pigs were weighed within 24 h after parturition and on d 14 and 28 of lactation. Litter size was equalized within each group of three sows assigned to the three diets until 3 d after parturition. Thus average litter size at d 3 was equal for the three treatments (9.9 pigs), but there were differences between

TABLE 1. COMPOSITION OF GESTATION AND LACTATION DIETS (G/D)

Ingredient	Gestation diet[a]	Lactation diets[b], Mcal ME/d 10	12	14
Cornstarch (IFN 4-02-889)		454	880	1,302
Tallow, bleachable fancy[c] (IFN 4-07-880)		283	340	397
Corn (IFN 4-02-992)	1,087	340	340	340
Soybean meal (IFN 5-04-604)	280	1,184	1,184	1,184
Beet pulp (IFN 4-00-669)	360			
Wheat bran (IFN 4-08-554)		567	567	567
Limestone (IFN 6-02-632)	4	54	54	54
Dicalcium phosphate (IFN 6-01-080)	41	50	50	50
Salt (IFN 6-04-151)	9	23	23	23
Trace mineral mix[d]	1	5	5	5
Vitamin mix[e]	18	45	45	45
Selenium premix[f]		2	2	2
Total feed/d	1,800	3,007	3,490	3,969

[a]The gestation diet was fed through d 108 of gestation and during the postweaning period. It contributed the following amounts (g/d) of protein, Ca and P: 254, 14.5 and 12.5, respectively, and provided 5.4 Mcal $ME \cdot sow^{-1} \cdot d^{-1}$.

[b]The lactation diets contributed the following amounts (g/d) of protein, Ca and P: 630, 36 and 24, respectively.

[c]Provided 22% of the daily energy intake for each of the lactation diets.

[d]Percentage composition was Zn, 20; Fe, 10; Mn, 5.5; Cu, 1.1; I, .15.

[e]Composition per kg of premix: vitamin A (stabilized), 2,750,000 IU; vitamin D_3 (stabilized), 220,000 IU; riboflavin, 1,450 mg; d-pantothenic acid, 11,000 mg; niacin, 11,000 mg; choline chloride, 110,000 mg; vitamin B_{12}, 11 mg; menadione sodium bisulfite, 1,100 mg; ethoxyquin, 2.2 g; vitamin E, 11,000 IU.

[f]Percentage composition was Se, .02.

groups of three sows. Creep feed was not available to pigs at any time.

After weaning, sows were moved into individual gestation stalls and were fed 1.8 $kg \cdot sow^{-1} \cdot d^{-1}$ of the gestation diet. They were moved, once daily, to a pen containing a boar to check for estrus. A sow was considered to be in estrus when she stood to be mounted by a boar on two consecutive days. There was one sow that stood for a boar for 1 d only. Estrous tests were continued for sows that had not previously exhibited estrus for a maximum of 70 d postweaning. Beginning on d 15 postweaning and weekly thereafter, any sow that had not been detected in estrus was bled for progesterone analysis. The procedures used for serum progesterone analysis, and the criteria for concluding that a sow had either exhibited behavioral estrus that was not detected, or had ovulated in the absence of estrus, were similar to those described previously (Nelssen et al., 1985).

Dietary effects on sow weight change and backfat change were tested using least-squares analysis of covariance (SAS, 1979; Steel and Torrie, 1980). Covariates included backfat thickness on d 110 of gestation, postpartum sow weight and litter size 3 d postpartum. For pig performance analysis the only covariate was litter size 3 d postpartum. The two degrees of freedom for treatment were divided into linear and quadratic (nonlinear) responses using orthogonal polynomials. Serum urea and creatinine concentrations were tested using split-plot analysis, with dietary treatment as the whole unit and bleeding time as the subunit (SAS, 1979; Steel and Torrie, 1980). A statistical model for categorical data (Grizzle et al., 1969) was used to test the effect of treatment on days to estrus postweaning. Treatment was the only classification variable included in the model.

Results and Discussion

The effect of energy intake during lactation on sow performance is presented in table 2. Sow weight loss during the first 14 d of lactation decreased (linear, $P<.001$) as energy intake increased. The same effect was also observed during the second 14 d of lactation. Consequently, sow weight loss during the entire lactation period was reduced linearly ($P<.001$) as energy intake increased. Similarly, backfat loss decreased linearly during the first 14 d ($P<.001$), the second 14 d ($P<.01$) and the entire lactation period ($P<.001$) as energy intake increased. The weight and backfat losses recorded in this experiment were similar to previous reports in which energy intake was restricted during lactation (Adam and Shearer, 1975; O'Grady et al., 1975; Reese et al., 1982a,b). Even when sows are given ad libitum access to feed they catabolize body tissue in early lactation (Stahly et al., 1979).

Average pig weight on d 14 of lactation increased linearly ($P<.05$) as sow energy intake increased (table 3). Likewise, average pig weight at weaning increased linearly ($P<.01$) as energy intake increased. Although the statistical model used did not test differences between individual means, pigs from sows fed 10 Mcal ME/d were lighter at weaning than pigs from sows fed either 12 or 14 Mcal ME/d. Litter weights on d 14 tended (linear, $P=.13$) to be heavier as sow energy intake increased, and increased linearly ($P<.05$) at weaning in response to sow energy intake. There were no differences ($P>.75$) in litter size at either d 14 or 28 of lactation.

The sow and litter data indicate that, although sows fed the lowest amount of energy catabolized more body tissue than sows in the two other groups, this did not fully compensate for their inadequate dietary energy intakes. In particular, the litter weaning weights illustrate that 10 Mcal ME/d was insufficient, whereas 12 Mcal ME/d was sufficient to maintain adequate lactation performance in primiparous sows. O'Grady et al. (1973) found that primiparous sows given energy intakes during lactation that ranged from 12.2 to 18.3 Mcal DE/d produced similar numbers and weights of pigs at weaning. In their experiment, however, pigs were given creep feed. More recently, Reese et al. (1982a) found that primiparous sows given 8 Mcal ME/d produced litters with lighter weaning weights than sows fed 16 Mcal ME/d. King and Williams (1984a) reported that pigs suckling sows fed 6.1 Mcal DE/d tended ($P<.10$) to grow more slowly than pigs suckling sows fed 13.9 Mcal DE/d. However, in a subsequent experiment (King and Williams, 1984b) there were no differences in pig growth rate when primiparous sows were fed either 6.1 to 6.5 Mcal DE/d or 12.7 to 14.2 Mcal DE/d. In both of the experiments of King and Williams (1984a,b), creep feed was introduced on d 14 and pigs were weaned between d 28 and 35. The NRC (1979) recommends a minimum energy intake during lactation of 12.8 Mcal ME/d for both primiparous and multiparous sows.

TABLE 2. EFFECT OF DIETARY ENERGY INTAKE DURING LACTATION ON SOW PERFORMANCE

	Energy intake, Mcal ME/d				P values[b]				
Item	10	12	14	CV[a], %	Trt	Rep	Wt 0[c]	Bf 0[d]	Pigs 3[e]
Number of sows	49	49	48						
Lactation wt change, kg[f]									
0 to 14 d	−9.1	−4.8	−1.6	95.8	.001[g]	.031	.001	.063	.001
14 to 28 d	−9.3	−6.8	−3.6	65.0	.001[g]	.416	.206	.160	.001
0 to 28 d	−18.4	−11.6	−5.2	57.0	.001[g]	.619	.001	.639	.001
Lactation backfat change, mm[f]									
0 to 14 d	−4.1	−3.3	−2.3	60.5	.001[g]	.439	.145	.250	.032
14 to 28 d	−4.3	−4.3	−2.7	68.1	.003[h]	.108	.500	.206	.028
0 to 28 d	−8.4	−7.5	−5.0	42.0	.001[g]	.785	.687	.063	.001
Percentage in estrus									
⩽ 7 d	81.6	87.8	87.5		.625				
⩽14 d	89.8	91.8	93.8		.781				
⩽21 d	91.8	91.8	97.9		.414				
⩽70 d	98.0	98.0	100.0		.910				
Number bled[i]	5	4	3						
Number with luteal activity before a detected estrus	0	1	0						

[a]Coefficient of variation.

[b]Probability values for the effects of treatment (Trt) and replication (Rep), and for the covariate effects of sow weight on d 0, sow backfat thickness on d 110 of gestation and for number of pigs on d 3.

[c]The average weight of sows on d 0 was 155.2, 152.9 and 158.4 kg for the groups fed 10, 12 and 14 Mcal ME/d, respectively.

[d]The average backfat thickness of sows on d 110 of gestation was 28.1, 28.0 and 28.4 mm for the groups fed 10, 12 and 14 Mcal ME/d, respectively.

[e]The average number of pigs on d 3 was 9.9 for each of the three groups of sows.

[f]Least-squares means.

[g]Linear effect of treatment ($P<.001$).

[h]Linear effect of treatment ($P<.01$).

[i]Sows bled for progesterone analysis if estrus had not been detected by 15 d postweaning.

TABLE 3. EFFECT OF DIETARY ENERGY INTAKE DURING LACTATION ON PIG PERFORMANCE

Item	Energy intake, Mcal ME/d			CV[a], %	P values[b]		
	10	12	14		Trt	Rep	Pigs 3[c]
Number of litters	49	49	48				
Pig wt, kg[d]							
14 d	3.7	3.9	4.0	13.8	.044[e]	.001	.187
28 d	6.3	6.7	6.7	12.1	.017[f]	.001	.003
Litter wt, kg[d]							
14 d	34.8	36.6	36.7	16.6	.223	.001	.001
28 d	57.8	61.5	61.7	14.7	.065[e]	.001	.001
Litter size[d]							
14 d	9.4	9.3	9.3	9.2	.948	.215	.001
28 d	9.2	9.2	9.2	9.9	.975	.053	.001

[a]Coefficient of variation.

[b]Probability values for the effect of treatment (Trt) and replication (Rep), and for the covariate effect of number of pigs on d 3.

[c]The average number of pigs on d 3 was 9.9 for each of the three groups of sows.

[d]Least-squares means.

[e]Linear effect of treatment (P<.05).

[f]Linear effect of treatment (P<.01).

Serum urea concentrations of sows are illustrated in figure 1. There was a treatment × time interaction (P<.001). Serum urea concentrations increased from d 110 of gestation to d 14 of lactation for sows in all treatments. Although differences between individual treatment means were not tested statistically, the increase was greater in sows fed 10 Mcal ME/d than in those fed either 12 or 14 Mcal ME/d. Furthermore, sows fed 12 Mcal ME/d had higher serum urea concentrations than sows fed 14 Mcal ME/d during the same period. Serum urea concentrations of all sows were lower on d 28 than 14 regardless of treatment. Sows fed 10 Mcal ME/d had higher serum urea concentrations than sows fed either 12 or 14 Mcal ME/d on d 28 of lactation, and sows fed 12 Mcal ME/d had higher concentrations than sows fed 14 Mcal ME/d.

Apparently amino acids are used as energy sources by lactating sows when their energy intake is restricted (Duee and Desmoulin, 1982; Reese et al., 1982a; Nelssen et al., 1985). Amino acid utilization for energy results in deamination, and subsequently urea synthesis in the liver. Thus, serum urea concentration is an index of amino acid degradation. In the present experiment, serum urea concentrations were inversely related to energy intake. It seems likely that when energy intake is insufficient, protein is catabolized to meet energy needs and this may result in a secondary protein deficiency. Previous research has demonstrated that protein deficiency during lactation results in increased sow weight loss (DeGeeter et al., 1972; Mahan and Grifo, 1975), reduced pig weights at weaning (Holden et al., 1968) and delayed return to estrus postweaning in primiparous sows (O'Grady and Hanrahan, 1975).

Previous evidence of protein catabolism by primiparous sows fed inadequate amounts of energy during lactation was presented by Nelssen et al. (1983). The authors were unable to distinguish whether the amino acids catabolized were derived from dietary or endogenous protein, or both. An elevation of serum creatinine concentration is often used as an index of muscle catabolism (Wallach, 1978). In the present experiment, serum creatinine concentrations were not affected by energy intake at either 14 or 28 d of lactation (figure 2). However, serum creatinine concentrations were numerically lower in sows fed 14 Mcal ME/d during lactation. Apparently muscle wastage

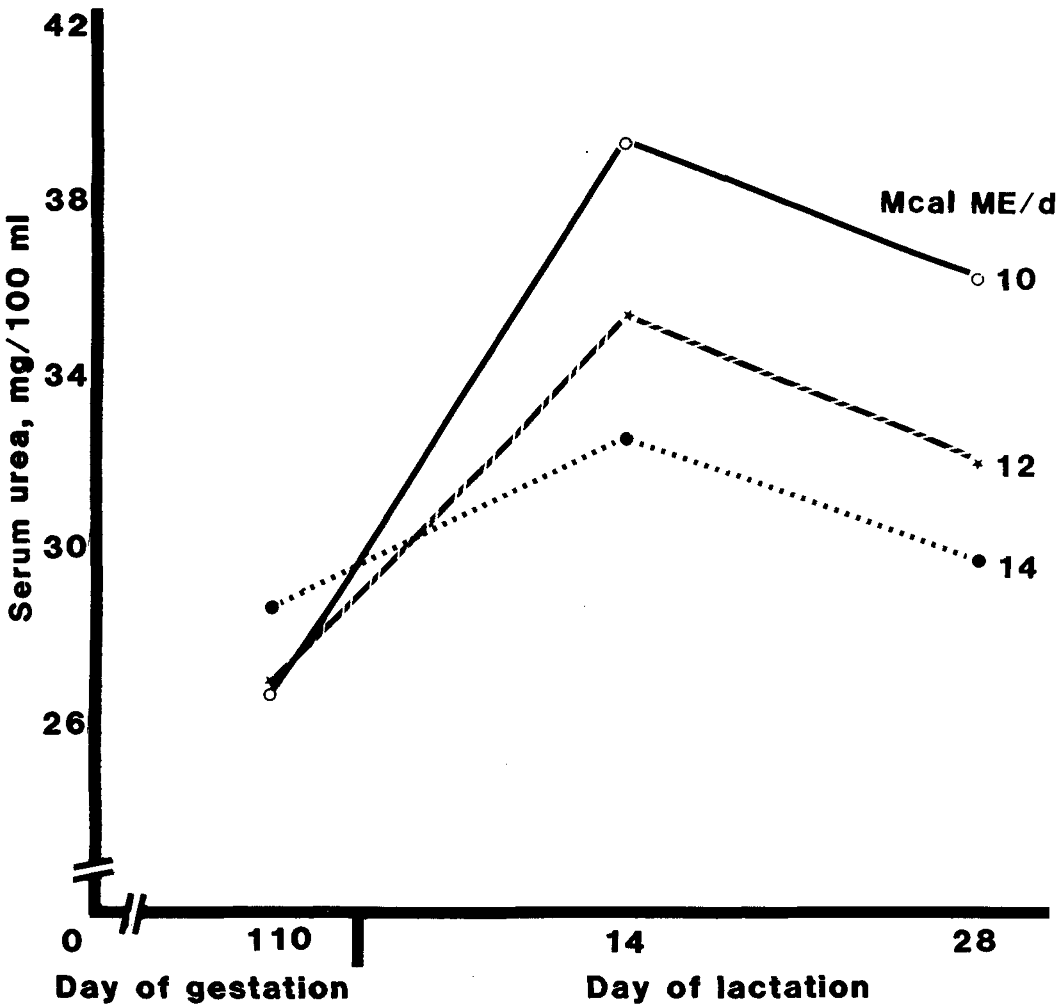

Figure 1. Serum urea concentrations of primiparous sows in late gestation and lactation. Sows were fed diets providing either 10 (○), 12 (∗) or 14 (●) Mcal ME/d. Treatment effect, P<.05. Treatment × time interaction, P<.001. Coefficient of variation, 18.2%.

may have been reduced in sows fed 14 Mcal ME/d.

The percentage of sows in estrus by 7, 14, 21 and 70 d postweaning was not different among treatments (table 2). However, sows fed 10 Mcal ME/d were slightly delayed in return to estrus postweaning compared with those fed either 12 or 14 Mcal ME/d. Previous research has found that energy restriction to 8 Mcal ME/d during lactation delayed return to estrus compared with 16 Mcal ME/d (Reese et al., 1982a). In their research, percentages of primiparous sows exhibiting estrus by 7 d postweaning were 65 and 96 for energy intakes of 8 and 16 Mcal ME/d, respectively. Percentage returns to estrus postweaning in the present experiment were intermediate between the values reported by Reese et al. (1982a). Thus, energy intake during lactation appears to influence directly the interval from weaning to estrus in primiparous sows.

Cox et al. (1983) found a delayed return to estrus in primiparous sows fed diets containing 9.6 Mcal ME/d during lactation. They also reported a seasonal variation in the interval from weaning to estrus. In the present study, replications were conducted during four different months to reduce any confounding effects of season.

One sow fed 12 Mcal ME/d, not detected in estrus by 15 d postweaning, was determined to have a serum progesterone concentration >5

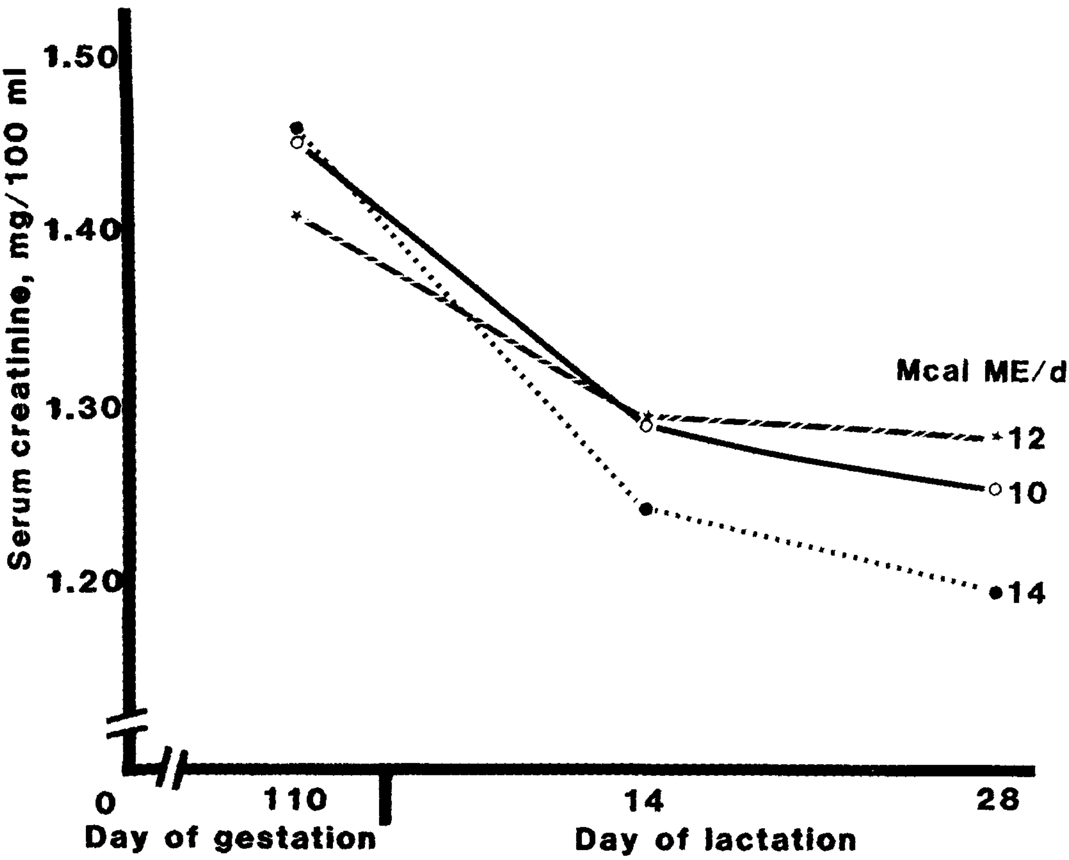

Figure 2. Serum creatinine concentrations of primiparous sows in late gestation and lactation. Sows were fed diets providing either 10 (○), 12 (•) or 14 (●) Mcal ME/d. Coefficient of variation, 16.5%.

ng/ml. This was considered to indicate the presence of luteal tissue activity. Thus, this sow either exhibited behavioral estrus that was not detected when exposed to a boar once daily, or had ovulated in the absence of estrus.

The findings of the present experiment indicate that energy intake during lactation has a direct influence on sow and litter performance. Energy restriction to 10 Mcal ME/d adversely affected sow weight change during lactation, reduced litter weaning weights and appeared to influence the interval from weaning to estrus. Based on the findings of this study, 12.8 Mcal ME/d as recommended by the NRC (1979) appears to be adequate for primiparous sows maintained for a single lactation. This experiment was terminated after the first lactation and rebreeding period. Thus, the energy requirement of primiparous sows to be retained for several parities was not determined.

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